Study of neutron-rich s-d-f shell nuclei

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Nuclei in the s-d-f shell exhibit a rich variety of phenomena and physics. In nuclei far away from β-stability the neutron-proton interaction $V_{\sigma\tau}$ can become a driving force in determining the nuclear structure. Examples of this effect can be found in neutron-rich oxygen and fluorine isotopes. The latter can bind many more neutrons (up to ^{31}F) compared to oxygen (up to ^{24}O). The so-called "island of inversion" is another manifestation of the increased importance of the strong $V_{\sigma\tau}$ interaction. In this case the interaction between valence $f_{7/2}$ neutrons and $d_{5/2}$ protons favors the "intruder configuration" (corresponding to the promotion of a pair of neutrons across the N=20 shell to the $f_{7/2}$ orbital) and causes several N~20 nuclei (e.g. ^{30}Ne, ^{31}Na, ^{32}Mg) to have deformed ground-states despite having a "magic" number of neutrons. Nuclei in this region have been mainly studied using reactions that are very selective. A more complete understanding of the nucleonic interplay and the underlying nuclear structure in the mass A~30 region can be obtained by applying less selective reaction mechanisms.

An experiment was performed at the ATLAS facility of the Argonne National Laboratory to populate neutron-rich A~30 nuclei utilizing the reaction ^{208}Pb(^{36}S,X) at 230 MeV. The target thickness of 0.5 mg/cm^2 was used to allow the reaction products to reach the particle detector. Identification of the target-like and projectile-like nature of the products as well as an event-by-event Doppler-shift correction was possible by utilizing the excellent spatial and timing resolution of the heavy-ion counter CHICO [1]. Gamma-radiation from the reactions was detected using GAMMASPHERE [2]. In addition to prompt gamma radiation the experiment was also sensitive to isomeric decay in the range of 10 ns to a few hundred ns. This allows for the search of new isomers in this mass region.

The preliminary analysis of the data set reveals a wealth of information on neutron-rich Cl, S, P, Si, and Al isotopes. To highlight the quality of the experimental data a spectrum gated on the 3860 keV line in ^{35}P (T=5/2) is shown in Fig. 1. The preliminary level scheme of ^{35}P is presented in Fig. 2. A new structure is found to feed the previously known (7/2$^-$) states. These negative-parity states are due to one neutron excitations from the s-d into the $f_{7/2}$ shell. The nature of the newly observed states is currently being investigated.

More s-d-f shell nuclei will be studied using this data set. The observed level structures and transitions will be compared to shell model calculations such as the Monte Carlo Shell Model using the SDPF interaction [3] and the Unified Shell Model Approach [4]. This comparison will test the models and help identify the underlying nuclear structure of the newly observed states.

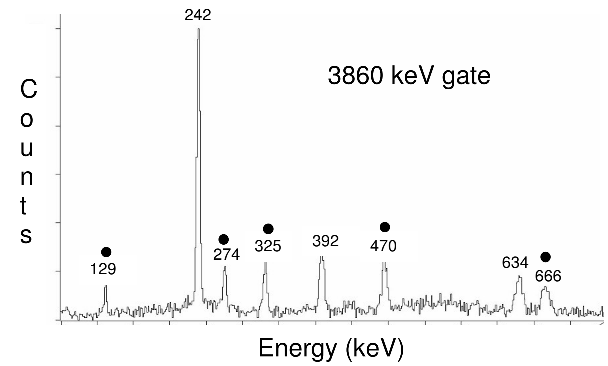

FIG. 1: Example of a spectrum gated on the 3860 keV line in ^{35}P. Solid circles above the gamma-ray energies indicate transitions observed for the first time.

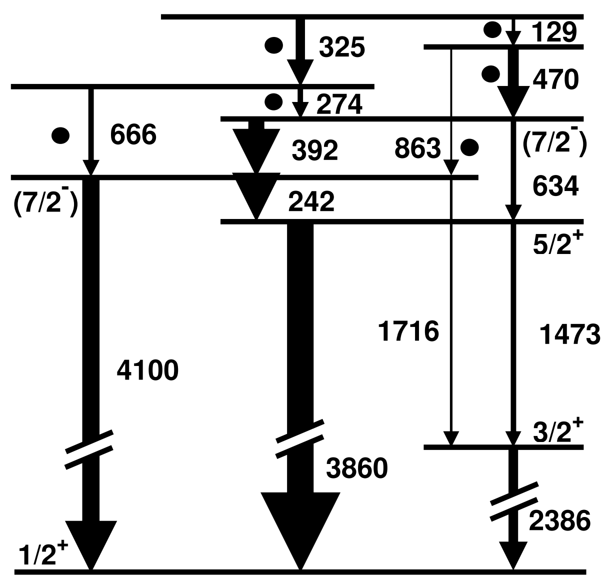

FIG. 2: Preliminary level scheme of ^{35}P. The widths of the lines indicate the relative strengths normalized to the 3860 keV line. Solid circles indicate new transitions.

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